

# **Broadband Acoustic Clutter**

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## **LONG TERM GOALS**

The long term goal is to improve performance of low-mid frequency active sonar systems against clutter.

## **OBJECTIVES**

The objectives are to identify/understand the mechanisms that lead to clutter and develop models that predict the temporal/spatial/frequency dependence of the observed clutter and background diffuse reverberation.

## **APPROACH**

The experimental approach is based upon exploiting both long-range observations of clutter and short-range, or direct-path observations (seabed scattering and reflection) of the features that give rise to the clutter. Direct path observations offer two significant advantages: a) the uncertainties associated with propagation (through a generally sparsely sampled ocean) are minimized, and b) the measurement geometries are favorable to producing data from which hypotheses about the scattering mechanisms can be directly tested. The theoretical approach for diffuse reverberation was taken and advanced from energy flux methods. This project is part of the Broadband Clutter Initiative Joint Research Project (JRP) including ARL-PSU (USA), DRDC-A (CAN), the NATO Undersea Research Centre (Italy) and NRL-DC (USA).

## **WORK COMPLETED**

A short summary of FY08 efforts include:

- 1) Quantified the uncertainties associated with inversion of reverberation data. Key result: reverberation predictions have large bias errors (order 10 dB+) even when there has been an REA or survey reverberation measurement and inversion in that same area. The origin of these errors is described in [1]. Also developed methods for mitigating those errors using one additional observation.
- 2) Analyzed clutter data from bottomed shipwreck (with Doug Abraham, Clutter'07 Experiment) to examine dependence of clutter statistics on multipath. Key result: in the shallow water

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environment on the Malta Plateau both modeled and measured statistics showed weak dependence on multipath [2].

- 3) Self-consistent sub-bottom reverberation, scattering, and clutter analyses. Key result: despite some claims to the contrary in the ocean acoustics community, sub-bottom clutter can and does occur in shallow water environments. A step-by-step detailed analysis shows the relation between the frequency and angle dependence of reflection, scattering, reverberation, propagation, and clutter in both theory and measurements [3]. The feature causing clutter in this case is a mud volcano buried ~3 m sub-bottom.
- 4) Analyzed/compared AUV seabed reflection measurements from Clutter'07 Experiment with Uniboom source (with Peter Nielsen and Chris Harrison, NURC). Key results: the AUV data generally look very promising; problems with time synchronization and source calibration created some anomalies in the data [4] which are being addressed in Clutter'09 planning.
- 5) New paradigm of geoacoustic uncertainties using perturbed physics approach. Developing capability to measure high-resolution range-dependent geoacoustic properties using single-bounce reflection observations. We are now tackling problems of variable parameterizations [5-7] (with Jan Dettmer and Stan Dosso, University of Victoria)
- 6) Coherence of seabed reflection is being exploited to obtain sediment geoacoustic fluctuations (roughness and/or volume heterogeneities) that are important for modeling scattering from the seabed [8] (with Laurent Guillon, Ecole Navale and his PhD student Samuel Pinson)
- 7) Made advances in energy flux reverberation predictions including multiple forward scattering. Almost all reverberation models currently make the single scatter approximation and the validity of this approximation in various environments is in question.
- 8) Assisted in the planning/organization of International Symposium on Reverberation and Clutter, Sept 9-12 2008, Lerici, Italy (with Peter Nielsen, Chris Harrison, Roger Gauss, Doug Abraham, Paul Hines).
- 9) Served on Data Definition Committee for the ONR-PMW-120 Reverberation Workshop II and participated in the workshop (Austin, TX, May 2008) including generating energy flux model results for many test cases. The energy flux solutions compare very well with more sophisticated (i.e., computationally intensive) models, e.g., coupled mode.

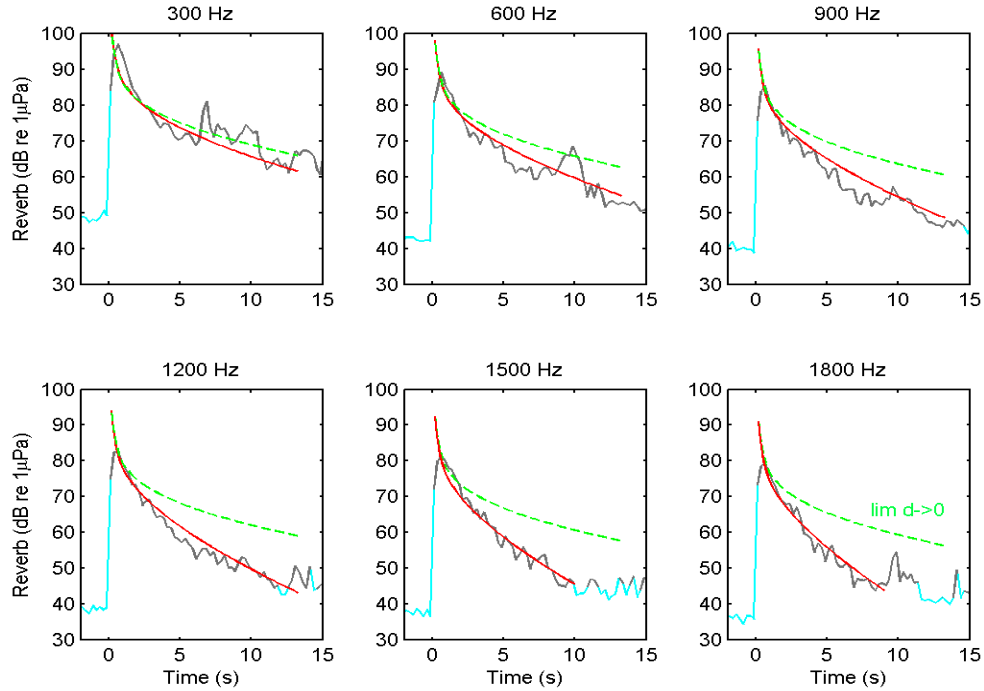
## RESULTS

### *Scattering from a sub-bottom mechanism*

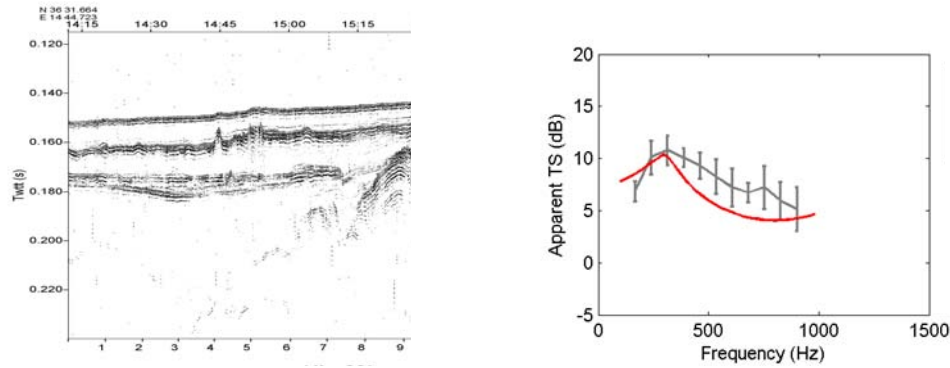
Seabed reflection, scattering, propagation and reverberation measurements were conducted in an area of the Straits of Sicily (Malta Plateau) where a thick layer exists (5-10m thick) composed of silty-clay sediment. As is typical with most silty-clays, the sound speed is less than that of the overlying water column and hence there is no critical angle. Thus, the reflection, scattering, propagation and reverberation are sensitive both to the layer properties as well as strongly influenced by the sub-bottom layer(s). The properties of the silty-clay layer and sub-bottom (including sub-bottom roughness) were completely constrained by the aforementioned measurements so that a comparison between measured and modeled reverberation could be made with no free (or adjustable) parameters (see Fig 1). The

good agreement substantiated the geoacoustic parameters. Also in Fig. 1, the green dashed line shows predictions without the silty-clay layer, showing that the frequency dependence of the reverberation (and we shall see the clutter) is largely controlled by the layer.

In this same area (which was flat and featureless with no biologics) the reverberation data showed clear evidence of clutter. Seismic reflection data across the clutter location showed that the clutter is associated with buried mud volcanoes (see Fig 2a). The reverberation beam-time series data were processed to obtain an estimate of the apparent target strength of the clutter feature over 9 different observations (8.2-10 km) using TL measured along a nearby track a few hours before the clutter experiment. There are two salient points about the measured apparent TS data (Fig 2b). First, the TS data show a peak around 300 Hz. This peak arises from the resonance effects in the fine-grained layer. Second, note the decrease in TS with increasing frequency which is due to attenuation within the layer. Model predictions using the geoacoustic data obtained by independent means (reflection and scattering data) show both behaviors. The only free parameter in this comparison was the unknown mud volcano (MV) target strength, which was assumed to be independent of frequency based on observations of proud MVs [9]. The scattering mechanism for the proud MVs was carbonate chimneys of order a few meters in radius, and the target strength data for the proud was roughly independent of frequency from 160 – 3600 Hz and averaged  $\sim 7$  dB. The fitted target strength for the buried MV was 14 dB and may be caused by scattering from larger and/or a greater quantity of carbonate chimneys. The good agreement between the shape of the modeled and measured TS helps confirm that the scattering is due to the sub-bottom features and opens the door to developing methods to classify sub-bottom and in-water targets.



**Figure 1. Measured reverberation on the Malta Plateau along 100m contour (cyan, gray portion has reverb-to-noise values  $>6$  dB); predicted reverberation (red) using parameters derived from seabed reflection and scattering data [3]. The prediction without the fine-grained sediment layers (green dashed) highlights the importance of the layer in controlling the frequency dependence of the reverberation.**



**Figure 2. a) seismic reflection data showing buried MVs at 14:45 time stamp, the silty-clay layer is generally ~8m thick and is 3m thick over the MV; b) measured (gray with st. deviation) and modeled (red) apparent target strength from buried mud volcanoes.**

## IMPACT/APPLICATIONS

The importance of these results is that they provide increased understanding of the mechanisms associated with sonar clutter in shallow water. The statistical characterization of these features will lead to clutter models that can be used in signal processing algorithms to predict and reduce the impact of clutter.

The reverberation uncertainty results have crucial importance to the survey community who are endeavoring to develop a bottom scattering database and associated survey measurement techniques. The results developed here are helping provide a basis for determining the suite of measurements required. Furthermore, direct-path scattering data collected under this program are providing badly needed mid-frequency observations for bottom scattering model(s) validation, a key step in database development.

Success of the AUV technique will open the door to 1) measuring small-scale features that lead to sonar clutter and 2) measurement of spatial variability (geoacoustic range dependence) at horizontal length scales of order  $10^2$  m and vertical length scales of  $10^{-1}$  m.

The multiple forward scattering modeling could provide a badly needed computationally tractable (i.e., fast) solution for accurate predictions of reverberation in rough environments.

## RELATED PROJECTS

*ONR/PMW-120 Reverberation Modeling Workshop II:* the workshop provided an outstanding forum for discussion of detailed issues regarding reverberation and clutter modeling which has been very useful for the Broadband Clutter project.

*ONR QPE:* Uncertainty: data/methods for quantifying geoacoustic uncertainty developed in this project are being leveraged to QPE

*PMW-120 OBCI Program*: Measurement results and techniques developed in this program are being transitioned to the survey community and also the 1<sup>st</sup> generation NAVO bottom scattering database.

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